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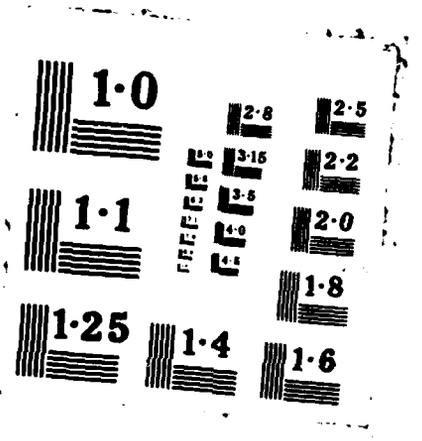
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of experimental studies were carried out in a large rainfall-erosion facility and in a large flume. Braided-stream experiments reveal that significant differences in the shape of bars, braiding index and channel behavior depend on channel gradient and sediment load. Deformation of a drainage network by uplift produced fractures that followed the drainage pattern. Incision of the pattern depends on rate of uplift, with slow uplift permitting lateral shift but rapid uplift producing vertical incision.

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The junction angles of drainage patterns change markedly at a surface slope of about 2%, and the effect of vegetation cover on erosion rates is minimal below 7% cover.

Multiple pediments formed, during experiments on the development of piedmont landforms, when piedmont drainages integrated and incised.

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EXPERIMENTAL GEOMORPHOLOGY

(Drainage Network, Piedmont and Channel Morphology)

FINAL REPORT

S.A. Schumm

15 October, 1987

U.S. ARMY RESEARCH OFFICE

Grant DAAG29-84-K-0189

Colorado State University

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Statement of Problem

This research involved attempts to investigate several classes of landforms and geomorphic processes as follows:

1) braided-stream morphology as affected by valley gradient and sediment load.
2) drainage networks and erosion rates as influenced by active tectonics, surface inclination and vegetative cover.
3) piedmont landform morphology and evolution

The first major objective was to determine how braided-stream and channel-bar patterns (number and shape) are affected by channel gradient and by sediment-load changes that lead to aggradation and degradation. If it could be established that channel morphology can be used to identify reaches of degradation and aggradation in the field the application of the technique to river engineering problems would be of substantial benefit.

The second major objective was to determine how active uplift affects drainage patterns. The recognition of active deformation in the field will be of value both to river engineers as well as to attempts to locate stable sites for the disposal of hazardous wastes and in the search for petroleum and natural gas. The quantification of the effect of the inclination of the surface upon which a drainage network has developed, on the drainage pattern will be of value in the interpretation of earth surface features from aerial photographs as well as leading to the prediction of the eventual pattern that will develop as actively eroding drainage network evolves.

Another aspect of this general problem of landform erosion is the need to determine the effect of small amounts of vegetative cover on slopes. This could be very important in erosion control efforts in semiarid and arid regions as well as in the interpretation of the effects of climate change in the drylands of the world.

The third major objective was to document the erosional evolution of pediments. Little is known about the development of these erosion surfaces, which are abundant throughout the western United States. A better understanding of these features could lead to a more complete geologic history in the west and further information on sediment production and ground water resources in piedmont areas.

Summary of Results

Each series of experiments and the results will be discussed under the headings of 1) braided-stream experiments; 2) drainage-network experiments and 3) piedmont-landform experiments.

Braided-stream experiments:

A braided river is a river having multiple flow paths or channels which diverge and converge around sub-aerially exposed bars and/or stable islands. Braided rivers are characterized by large sediment load, high bedload to total load ratio, and high energy owing to steep gradients.

The specific objectives of the braided-stream experiments research were:

1) to gain a more complete understanding of bar forming processes based upon direct observations,
2) to determine how changes in valley gradient (energy) affect braided-river morphology,
3) to determine if sediment caliber affects braided-river morphology and processes of bar development, and
4) to examine the effects of sediment load on braided-river morphology.

Experiments were conducted in an outdoor, tilting flume at the Engineering Research Center at Colorado State University. This flume had not been used for many years. It was moved to a position near the REF and modified to conform to the needs of the research. This flume is now a permanent part of the geomorphic research facilities and it can be used for this type of research in the future. The flume is mounted on 15 pairs of screw jacks which allows the flume gradient to be varied from 0 to 4%. Water is introduced into the headbox through a plastic pipe 10.16 centimeters in diameter. Fluid turbulence is dampened by a wooden, rectangular-grid energy dissipator in the headbox.

Sediment is introduced at the head of the experimental channel via a syntron vibrating sediment feeder. Sediment which is transported through the flume can be caught in a framed screen at the tail box exit pipe, and total sediment discharge can be calculated by measuring the volume of sediment trapped in a sump box below the tail box. The flume was filled to depth of approximately 0.25 meters with unconsolidated sediment. Sediment with two different grain size distributions were used. One set of experiments (28 runs) were conducted using coarse sand (D_{50}= 0.6mm; D=0.87mm) and another set of experiments (15 runs) were completed using very fine pebbles (D_{50}=1.9mm; D=2.19mm).

A total of forty-three experimental runs were completed; thirty eight channels were mapped, and they serve as the main data set for this report, three were purely observational runs, and three runs were designed to serve as the basis for sedimentologic analysis. Experiments were conducted at four different flume gradients, 1.5%, 2.25%, 3.00%, and 3.75%. At each gradient at least one complete set of three experiments were completed, each having different sediment input. A normal set of experiments consisted of: 1) an equilibrium run, 2) an aggradational run (sediment input being as great as can

be moved away from the sediment feeder and greatly exceeding sediment output), and 3) a degradational run (no sediment feed). The aggradational and degradational runs were designed to represent worst-case scenarios, severe overloading and no sediment feed respectively, in order to insure that significant aggradation and degradation would occur.

Bar Development

By definition, subaerially exposed mid-channel bars are a necessary component of the braided pattern. In this study, bars have been separated into two basic types: 1) linguoid bars, and 2) braid bars. The results of this research suggests that his relatively simplified classification is sufficient for present purposes and perhaps also in the general sense.

Linguoid bars are submerged, parabolic or lobate-shaped positive bed elements bounded by avalanche faces along downstream margins. Although the parabolic or lobate shape is most common, many bars have sinuous or multi-lobed margins which form in response to local variations in the intensity and direction of the main flow paths. These bars are dynamic features, which actively migrate through the channels. Therefore, they occur in zones of high bed-load sediment transport, and they are a primary mechanism of bed-load transport.

Braid bars are stationary, subaerially exposed bars which are essentially sites of sediment storage. Braid bars are elongate, and they are oriented parallel or sub-parallel to flow. They are referred to as braid bars because they separate flow into distinct channels. Braid bars are formed in the flume in three ways:

1) local scour of a linguoid bar leaves a portion of the bar subaerially exposed and stationary,

2) local flow shifts and scour leaves a portion of the bed subaerially exposed as a braid bar,

3) bed load is deposited particle by particle in an area of local flow divergence in a fashion similar to that described by Leopold and Wolman (1957).

Of these, the first process is unequivocally responsible for the overwhelming majority of braid bars present in the experimental channels. The creation of braid bars by means of linguoid bar dissection is a dynamic process resulting from the interaction between flow and bar shape. Repeated observations of the growth of braid bars reveals that once a bar forms, it grows by: 1) further exposure of the initial linguoid bar, as flow shifts away from the newly formed exposed bar, 2) accretion of linguoid bar margins, as flow shifts from the exposed bar, and 3) further accumulation of bed load, grain by grain, as flow shifts away from the deposit. Once exposed, braid bars are further molded by fluid shear into their characteristic streamlined, longitudinal shapes. Thus, exposed braid bars are most commonly depositional features that have been eroded to their final characteristic form.

Flume Gradient and Braided River Morphology

As flume gradient is increased, exposed braid bars become more elongate and braid bar length-width ratio increases. Figure 1 illustrates the relationship between braid bar geometry and flume gradient; especially for the gradient range between 2.25% and 3.75%. Field measurements of bar geometry in two reaches of Sand Creek, in Aurora, Colorado and from detailed topographic maps of the Rio Grande River in New Mexico reveal similar trends. The average length-width ratio of 59 braid bars measured just west of Chambers Avenue in Sand Creek, where channel gradient was 0.58%, was 5.71. In contrast, 75 braid

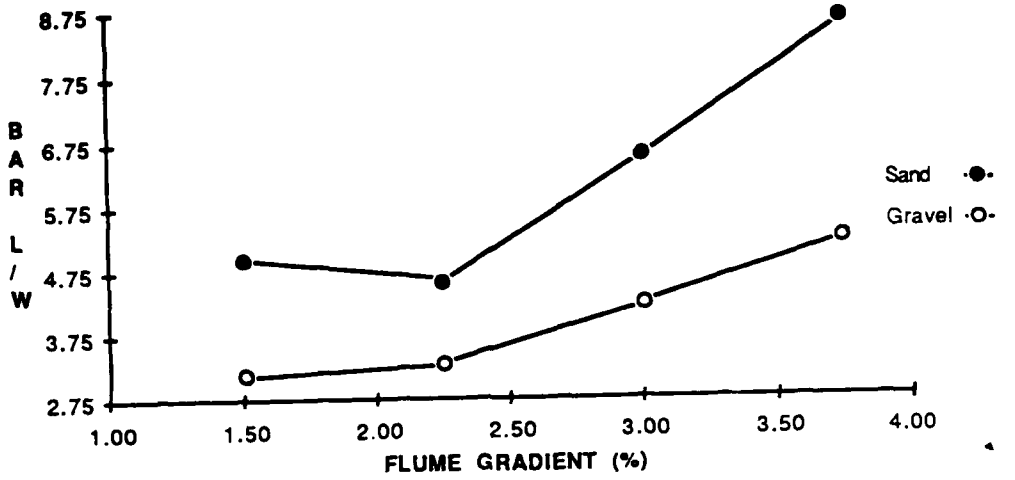

Fig. 1. Effect of gradient on bar shape (length-width ratio) for sand and gravel channels.

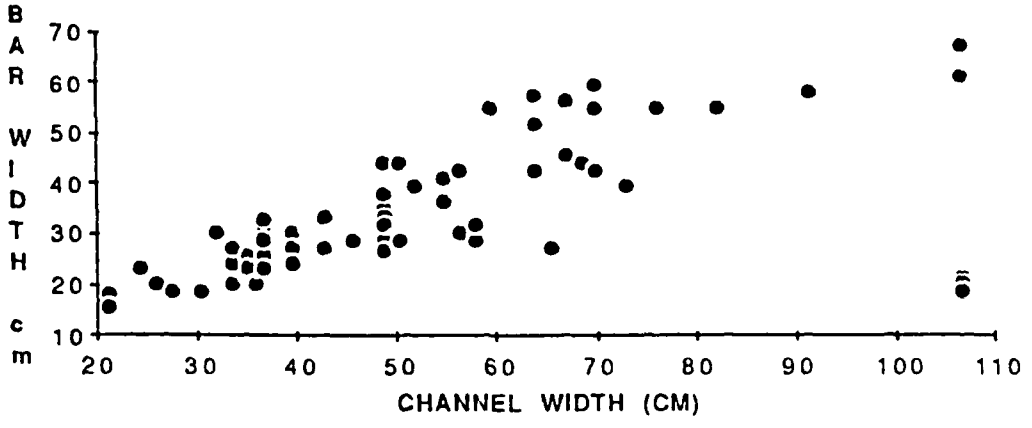

Fig. 2. Effect of channel width on width of linguoid bars in gravel channel.

bars measured just east of Interstate Highway 225 had an average length-width ratio of 3.41 and a channel gradient of 0.45%. As the Rio Grande River channel gradient increases from 0.07% to 0.10% across the Socorro magma body, the average length-width ratio of mid-channel braid bars increases from 4.38 to 5.12. Although the exact values are not the same as those measured in the flume, the overall trends are consistent.

The main conclusion to be drawn from the relationship between braid bar geometry and flume gradient is that, although subaerially exposed braid bars are depositional features, they have erosional, streamlined forms that can be related to channel gradient.

In contrast to braid bars, horseshoe-shaped linguoid bar geometry bears no consistent relationship to flume gradient. Rather, linguoid bar geometry appears to be affected more by channel width. Figure 2 illustrates that in general, linguoid bar width increases with an increase in channel width for the gravel channels, but the coefficient of correlation (R^2) for the least squares regression equation:

$$\text{Bar width} = 0.23 * \text{channel width} + 20.66 \qquad R^2 = 0.221$$

clearly indicates that the relationship is not strong when all linguoid bars (sand and gravel) are combined.

Measurements taken from 52 linguoid bars in two reaches of Sand Creek, Colorado show that linguoid bar width is related to channel width (Figure 3) as described by the least squares regression equation:

$$\text{Bar width} = 0.82 + \text{channel width} - 0.02 \quad R^2 = 0.867.$$

Measurements taken from large scale, high resolution photos of the Platte River near Grand Island, Nebraska indicate that, although the same general trend is discernable, the relationship is very poor once channel width is such that several bars can coexist adjacent to each other.

Grain Size and Braided River Morphology

As described earlier, grain size had little effect on the overall sequence and processes of bar development. Grain size did however, affect several aspects of braided river morphology. As illustrated by Figure 1, braid bar geometry is affected by grain size at any given gradient, braid bars formed in coarse sediment (gravel) will have, on average, lower length-width ratios than those formed in sand. Because the braid bars are erosional and essentially represent a balance between energy available (total stream power) and resistance to transport (grain size) the relationships illustrated in figure 1 are not surprising.

Channels developed in the coarse sediment are more braided than the sand channels. This is reflected by an increase in braiding index from an average of 3.80 for all sand channels to 5.17 for all gravel channels.

The braiding index used here differs from that of Brice (1964) in that it includes the number of bars present per unit length of channel as follows:

$$B.I. = 2\left(\frac{\text{sum of length of bars in a reach}}{\text{length of reach}} + \frac{\text{total of bars}}{\text{length of reach}}\right)$$

Braided channels formed in the fine gravel are also characteristically more rugged topographically, as indicated by an increase in bed relief index (B.R.I.) from 4.21 for sand channels to 7.92 for gravel channels.

The increase in bed ruggedness is also reflected by a relative increase in linguoid bar amplitude of 0.477 cm for sand bars to 1.033 cm for gravel bars. The overall increase in the ruggedness of bed topography is similar in trend to the relative decrease in bed relief index corresponding to decrease in grain size in the downstream direction on the Platte River described by Smith (1970).

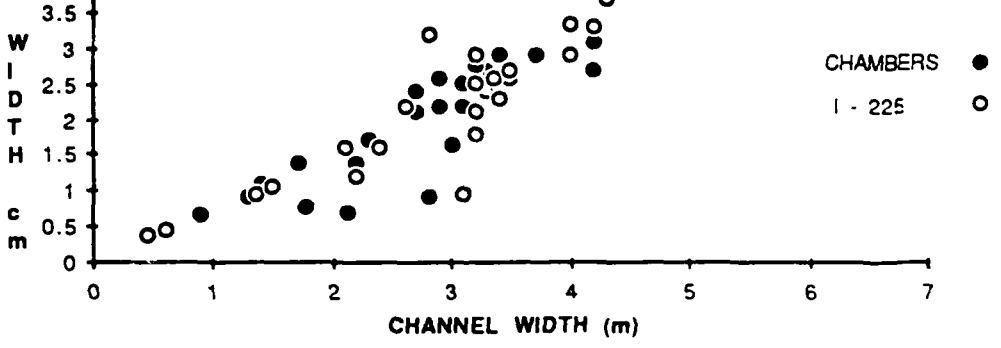

Fig. 3. Effect of channel width on width of linguoid bars, Sand Creek, Colorado.

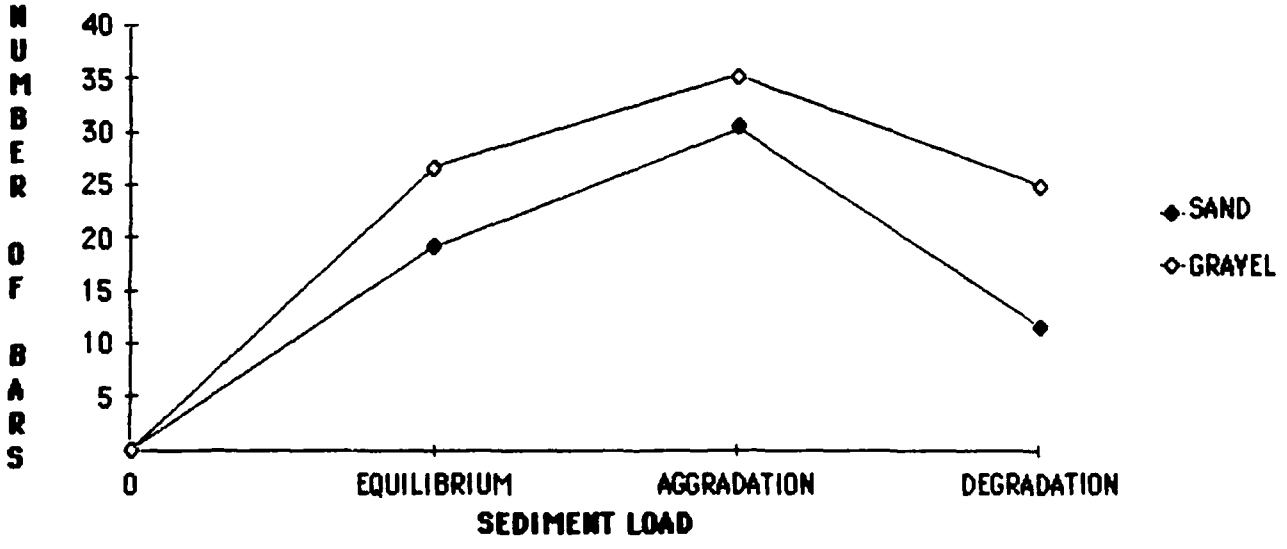

Fig. 4. Number of braid bars formed in equilibrium, aggrading and degrading channels.

Sediment Load and River Morphology

Equilibrium braided channels are characterized by multiple flow threads, which weave around subaerially exposed sand or gravel bars and which act as sediment storage sites. The pattern is considered to be an equilibrium pattern because: 1) although bars are continually formed and destroyed the overall character of the pattern remains essentially the same, 2) sediment discharge is roughly equivalent to sediment input, and 3) there is not excessive channel scour, nor excessive deposition owing to lack or overabundance of sediment input. As sediment input is increased in order to generate overall channel aggradation, sediment discharge also tends to increase; however, most of the excess sediment is stored in the channel. The most obvious result of this sediment storage is an increase in the number of exposed braid bars present in aggrading channels (Figure 4).

When sediment input is cut to zero, the channels actively degrade and the trends described above are generally reversed. In both sand and gravel channels the total number of bars present decreases drastically (Figure 4), but average individual bar area increases. A decrease in the number of bars present in degrading channels directly results in a decrease in the braiding index. The number of bars present decreases for two reasons: 1) the sediment-free water totally consumes a certain number of bars, and 2) as the main channels locally scour more deeply, smaller bar-bisecting channels are left high and dry; hence, two smaller bars essentially coalesce to form one larger bar. This also explains in part, the average increase in individual bar area.

The total number of bars decreases more in degrading sand rivers than in degrading gravel rivers because of an overall pattern change, which is unique to the sand channels. Degrading sand rivers undergo a channel pattern transformation with upstream reaches scouring deeply and forming a single

channel flanked by a series of terraces (Figure 5). Therefore, overall bar numbers are reduced significantly, as the pattern is transformed from multiple to single thread in the upstream area. Downstream reaches remain braided long after the upstream reaches become a single channel, and in fact, continue to aggrade as pulses of sediment are released from the deeply scoured reach upstream.

Summary:

The results of this study suggest that bar classification in braided channels can be consolidated into two basic types: 1) slipface bounded, parabolic shaped, subaqueous linguoid bars which actively migrate through the channels, and 2) elongate, subaerially exposed, stationary braid bars which separate flow into distinct channels, and form primarily from dissection and accretion of linguoid bars. With an increase in flume gradient, braid bars become more elongate in both coarse and fine grained sediment; however, braid bars formed in sand channels are more elongate than bars formed in gravel channels at any given gradient. Also channels formed in gravel tend to be more braided than the sand channels.

These experiments also illustrate that changes in sediment supply significantly affect braided-river morphology. As sediment supply is increased, the total number of braid bars increases as more sediment is stored and the channels become more braided. At the same time average braid-bar size tends to decrease slightly. In sand channels when sediment supply is reduced to zero, the pattern may be transformed completely to a single thread channel, but only after a period of adjustment marked initially by continued deposition downstream. In the gravel channel, decreased sediment load leads to an overall

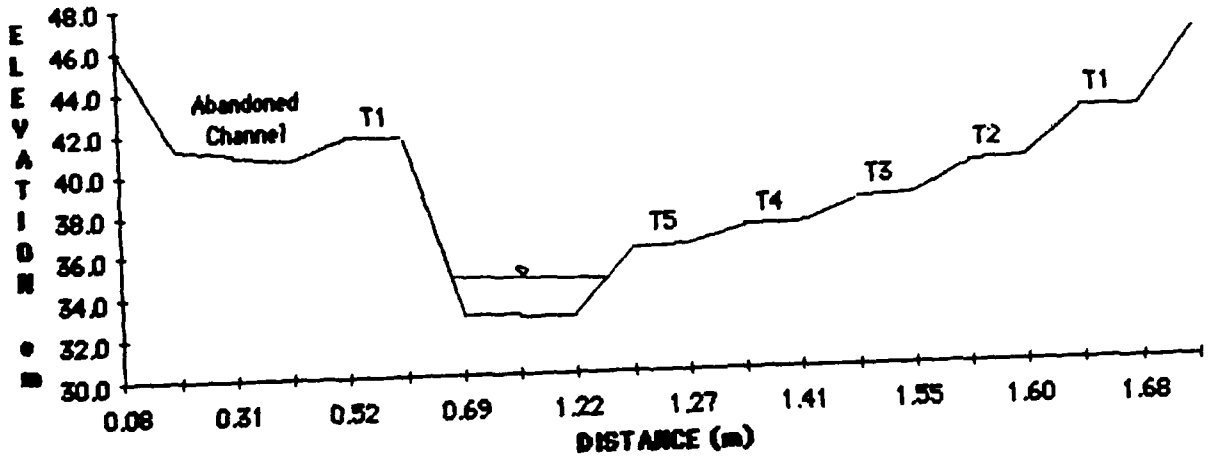

Fig. 5. Cross section in upper part of flume showing multiple terraces that formed during a degradation.

decrease in braiding, but the response is not necessarily uniform through the system.

Drainage Basin Experiments

Active Tectonics

The response of the fluvial system to aseismic tectonic deformation has been studied in areas of salt domes and anticlinal deformation. It was the purpose of this study to simulate uplift in a controlled experimental environment. The investigation was performed in the Rainfall Erosion Facility (REF) at the Engineering Research Center of Colorado State University. The REF is a large rectangular box 9.1 meters wide by 15.2 meters long. It is approximately 1.8 meters deep. Precipitation is applied by flow through 7 irrigation nozzles of 2 different sizes approximately 4 meters above the watershed surface. Uplift was accomplished by inflation of a 3.0 meter wide octagonal snow pillow that was buried approximately 0.76 meters below the surface. Prior to all runs, the surface was graded in the configuration of two intersecting planes with the line of intersection at the center of the REF. The slope from the divide to mouth in the center of the basin was 2.5% with a 0.7% slope towards the center line of the basin axis. The effect of uplift in 1 cm increments was observed initially in order to determine the fracture pattern in the absence of surface features. Fractures propagated outward from the center of the dome progressively with uplift to form a radial fracture pattern with a central graben. After determining the nature of the fracture pattern that developed during uplift, six experiments were performed.

The uplift in Run 1 was initiated after a dendritic drainage pattern had formed to the stage of maximum extension. A significant pattern of faulting emerged from this run. Figure 6 shows the fracture pattern and drainage

pattern over the dome after this uplift. The up-basin side of the dome exhibited faulting down the center of the stream valleys whereas on the down-basin side of the dome some faulting occurred that was discordant with the orientation of the valleys. It is apparent that the fracturing of the surface was influenced by the topography of the surface even though the channels were incised to a depth of only 11 percent of the total depth to the top of the snow pillow. Therefore, seemingly insignificant surficial features may greatly affect the location of the release of the tensile stresses that exist in an area of uplift. As the run continued the streams subsequently exploited the valley controlled fractures since these fault areas were now zones of weakness. The channel incised and little lateral stream migration occurred during the remainder of the run. However, on the down-basin side of the dome, where some fractures were discordant with the streams, the streams did migrate laterally.

The magnitude of uplift over specific areas of a dome may also be influenced by the topography. Five benchmarks were monitored during the final 15.5 hours of Run 1. The benchmarks were placed in a square pattern half the distance from the center to the edge of the dome. In addition a benchmark was placed at the center of the dome. The benchmarks showed 15 percent greater uplift on the downstream side of the dome where greater erosion occurred.

The time of uplift had significant influence on drainage pattern formation and modification. During Run 2, uplift was initiated prior to the application of precipitation. The uplift formed radial cracks 3 to 4 cm wide and 15 cm deep over the dome surface. When precipitation was started, runoff followed the cracks from the up-basin side of the dome to the down-basin side thereby forming drainage lines through the pre-existing structure. This mechanism of dome dissection may require a very competent rock material within the fault sidewall or a very rapid uplift rate. Poorly competent material will erode and

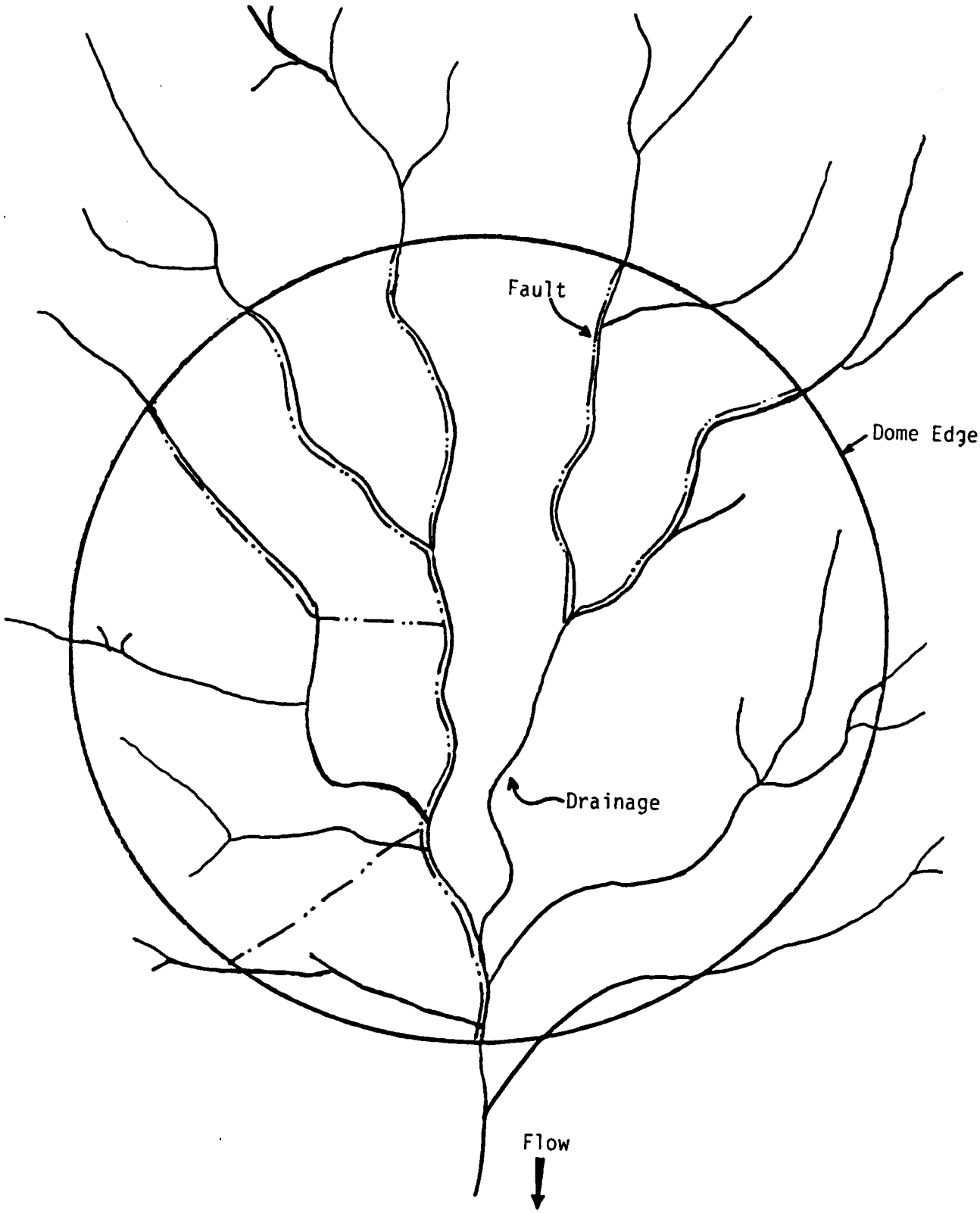

Fig. 6. Fracture pattern that developed during deformation of an existing drainage pattern (Run 1).

fill in the fault at a rate faster than the rate of crack formation, and therefore, the drainage will be diverted around the dome.

The streams in Run 3 showed repeated stages of lateral migration. As the dome was uplifted the area of uplift increased outward from the center with time. Lateral stream migration occurred and continual lateral shifting with periodic trenching formed terraces sloping towards the channel when a knickpoint migrated through the dome.

Experimental runs 4 through 6 tested the response of a dendritic drainage pattern to different rates of uplift. During Run 4 with the highest rate of uplift the least amount of drainage pattern modification occurred. Very little lateral stream migration occurred, but incision was pronounced. The longitudinal profiles showed little modification in character during rapid uplift. A slight increase in gradient did occur in the main stream however no convexity was noted. A total of four terraces were noted at the end of the run. The channel responded to the uplift by narrowing the bed of the stream. Only moderate sediment storage in the channels occurred upstream of the dome.

The highest degree of drainage pattern modification occurred during Run 5. The uplift rate was 1/2 of the rate of Run 4. During Run 5 there was significant lateral migration of the stream. The stream at this slower rate of uplift maintained its gradient by meandering and not by significant incision. It is therefore evident that the response of a stream to vertical deformation is dependent upon the rate of the uplift even though the total uplift in each case might be the same. The stream responded to the rapid uplift by eroding its bed, whereas during lower uplift rates, bank erosion causing meandering.

Additional studies in the REF on the effect of surface slope on drainage networks have been reported by Phillips and Schumm (1987). Recently completed experiments involving varying percentages of vegetational cover suggests that

erosion is either not affected by an increase of vegetative cover from 0% to 7% or the vegetation may actually increase sediment yields by aiding in the development of rills. Only preliminary results are available, and the analysis of the experimental results is continuing.

Summary:

The experimental results suggest that dendritic fracture patterns may result from the development of fractures in existing valleys. Therefore, fracturing above an uplift may be closely related to pre-existing topographic features. Rates of uplift influence drainage pattern response to uplift. Slow rates permit lateral shift and channel adjustment by meandering. Rapid rates of uplift cause incision.

Fracturing across uplifts may provide paths for the development of drainage lines that are neither antecedent nor superimposed but rather are contemporaneous with the uplift. Temporary damming of flow above an uplift will permit overtopping of the structure, with the development of cross-structure "fracture-fluvial" canyons.

Piedmont Landforms (Pediment formation)

The piedmont is an area at or near the base or foot of a mountainous area (Twidale, 1968). Piedmont landforms include alluvial fans, bajadas, pediments, and pediment remnants. Alluvial fans and pediments constitute a loose end-member series, that of deposition (alluvial fans and bajadas) and erosion (pediments and pediment remnants).

Gilbert (1877) first recognized and described pediments in Utah's Henry Mountains. McGee (1897) is credited with actually creating the term "pediment" for the low angle erosional bedrock surfaces he observed. McGee proposed flash

floods or sheet floods as responsible for pediment formation after nearly losing his party's horses to one such flash flood.

The results of the experimental studies of pediment formation and scarp retreat in the REF were disappointing. First the selection of materials to form the scarp and a caprock consumed on inordinate amount of time. Five experiments were performed, and changes of piedmont landforms were documented. Major changes required a lowering of baselevel.

The results show regrading of the pediment, as the scarp retreats, but perhaps more important for the interpretation of multiple pediment surfaces that lie at the base of major escarpments, such as the Book Cliffs in western Colorado and eastern Utah, the integration of parallel drainage on a pediment slope concentrates flow and produces incision, which in turn produces at least two erosion surfaces without a baselevel change.

The results also show that pediment formation requires low sediment production from the scarp. This is in contrast to the development of the other end member of piedmont landform series, the alluvial fan, which requires abundant sediment delivery to the scarp base.

Although data analysis continues, the major conclusion to be drawn from this series of experiments is that flow integration on a pediment surface can lead to incision and formation of multiple pediments.

References

Brice, J.C., 1964. Channel patterns and terraces of the Loup Rivers in Nebraska. U.S. Geol. Survey Prof. paper 422-D. 41 p.

Gilbert, G.K., 1877. Report on the geology of the Henry Mountains. Government Printing Office, Washington, D.C. 160 p.

Leopold, L.B., and Wolman, M.G., 1957. River channel patterns: braided, meandering, and straight. U.S. Geol. Survey Prof. Paper 262-B, p. 39-85.

McGee, W.J., 1897. Sheetflood erosion. Geol. Soc. of Amer. Bull., v. 8, p. 87-112.

Phillips, Loren and Schumm, S.A., 1987. The effect of regional slope on drainage patterns. Geology, v. 15, p. 813-816.

Smith, N.D., 1970. The braided stream depositional environment: Comparison of the Platte River with some Silurian clastic rocks, North-Central Applachians. Geol. Soc. Amer. Bull., v. 81, p. 2933-3014.

Twidale, C.R., 1968. Pediments. In Fairbridge, R.W. (ed.) Encyclopedia of Geomorphology, Reinhold, N.Y., p. 817-818.

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